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The Effects of Emotional Lability, Mind Wandering and Sleep Quality on ADHD Symptom Severity in Adults with ADHD

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Abstract

Mind wandering, emotional lability and sleep quality are currently mostly independently investigated but are all interlinked and play a major role in adult attention-deficit/hyperactivity disorder (ADHD). Emotional lability is a core feature of the disorder, excessive mind wandering has recently been linked to symptoms and impairments of ADHD and poor sleep quality is experienced by a clear majority of adults with ADHD. All three phenomena lead to functional impairment in ADHD, however their relationship to each other and to ADHD symptom severity is not well understood. Here we used serial multiple mediation models to examine the influence of mind wandering, sleep quality and emotional lability on ADHD symptom severity. 81 adults diagnosed with ADHD participated in this study. We found that mind wandering and emotional lability predicted ADHD symptom severity and that mind wandering, emotional lability and sleep quality were all linked and significantly contributed to the symptomatology of adult ADHD. Mind wandering was found to lead to emotional lability which in turn led to ADHD symptom severity; and poor sleep quality was found to exacerbate mind wandering leading to ADHD symptoms. Future research should employ objective on-task measures of mind wandering, sleepiness and emotional lability to investigate the neural basis of these impairing deficits in ADHD.

Key Words: Attention-deficit/hyperactivity disorder, adults, mind wandering, sleep quality, emotional lability

Introduction

ADHD and Emotional Lability

Attention-deficit/hyperactivity disorder (ADHD) is a pervasive neurodevelopmental disorder affecting 5-6% of children and 3-4% of adults (Fayyad, De Graaf et al. 2007, Polanczyk, de Lima et al. 2007). In both children and adults ADHD is characterized by age-inappropriate and impairing levels of inattention, hyperactivity and impulsivity (Faraone, Asherson et al. 2015). According to DSM 5 measures of emotional lability can be used in a supportive capacity to help establish the diagnosis of adult ADHD. This can include a number of symptoms such as high irritability, changing moods or low frustration threshold (APA 2013). Emotional lability is also a prominent feature of borderline personality disorder and bipolar disorder (APA 2013), which are both common comorbidities of ADHD (Kessler, Adler et al. 2006, Moukhtarian, Mintah et al. 2018). However, it has been argued that emotional lability in adults with ADHD is not related to comorbid conditions, but is a core feature of the disorder (Asherson, Buitelaar et al. 2016). This is supported by multiple lines of evidence: emotional lability is present in adults with ADHD without psychiatric comorbidities (Skirrow and Asherson 2013), it responds well to ADHD medication (Skirrow, McLoughlin et al. 2009, Moukhtarian, Cooper et al. 2017) and is related to functional impairment beyond other symptoms of ADHD (Barkley and Fischer 2010). Moreover, genetic studies indicate shared genes explain the strong link of ADHD to emotional lability (Merwood, Chen et al. 2014).

ADHD and Mind Wandering

Mind wandering is an omnipresent life experience, when our mind drifts away from a primary task and focuses on internal, task-unrelated thoughts and images. It has been defined as a shift of

attention from the external environment towards inner, self-generated, task-unrelated and stimulus-independent thoughts, decoupled from immediate sensory perceptions (Stawarczyk, Majerus et al. 2011, Smallwood and Schooler 2015). It is estimated that up to 50% of our daily lives are spent in a mind wandering state (Kane, Brown et al. 2007, Killingsworth and Gilbert 2010). Mind wandering can be spontaneous and unintentional, which is often detrimental to the task at hand and have little strategic value to the individual; or deliberate, when it may be related to strategic thinking about future plans (Seli, Risko et al. 2016). Excessive spontaneous mind wandering has recently been proposed as a candidate mechanism leading to the symptoms and impairments of ADHD, as it correlates strongly with ADHD symptom domains and impairment scores (Seli, Smallwood et al. 2015, Mowlem, Skirrow et al. 2016, Franklin, Mrazek et al. 2017, Bozhilova, Michelini et al. 2018), and mind wandering is closely associated with default mode network (DMN) activity (McKiernan, D'Angelo et al. 2006, Mason, Norton et al. 2007, Fox, Spreng et al. 2015) and dysregulation of the DMN is a prominent feature of ADHD (Bozhilova, Michelini et al. 2018). Mind wandering and ADHD symptoms have been examined predominantly in populations of college students not diagnosed with ADHD (Shaw and Giambra 1993, Seli, Smallwood et al. 2015, Franklin, Mrazek et al. 2017, Jonkman, Markus et al. 2017). These studies found that spontaneous mind wandering is positively associated with ADHD symptom severity (Seli, Smallwood et al. 2015), both when measured in the laboratory as well as in daily life (Franklin, Mrazek et al. 2017). Participants with a childhood diagnosis of ADHD reported more task-unrelated thoughts compared with other participants (Shaw and Giambra 1993).

ADHD and Sleep Quality

Poor sleep quality and the resulting sleep deprivation have profound consequences on daily human functioning, negatively affecting cognition and emotion (Krause, Simon et al. 2017). Lack of good quality sleep disrupts normal wakefulness resulting in inattention (Pilcher and Huffcutt 1996, Dinges, Pack et al. 1997, Durmer and Dinges 2005). Excessive daytime sleepiness due to disrupted sleep is

extremely common in the general population (Lund, Reider et al. 2010) as well as in children and adults with ADHD (Cortese, Faraone et al. 2009, Hvolby 2015). Furthermore, adults with ADHD report higher excessive daytime sleepiness relative to healthy controls (Bjorvatn, Brevik et al. 2017). A variety of sleep problems are associated with ADHD (Konofal, Lecendreux et al. 2010). It is estimated that up to 78% of adults with ADHD experience sleep problems (Yoon, Jain et al. 2012, Kooij and Bijlenga 2013) and report lower sleep quality than neurotypical controls (Boonstra, Kooij et al. 2007, Schredl, Alm et al. 2007, Sobanski, Schredl et al. 2008, Surman, Adamson et al. 2009). Sleep problems are thought to add to lower quality of life in ADHD, and are also associated with poorer academic performance, obesity, as well as more negative relations with carers (Um, Hong et al. 2017). Sleep disorders may also generate ADHD-like symptoms which can make differential diagnosis challenging (Oosterloo, Lammers et al. 2006, Bioulac, Micoulaud-Franchi et al. 2015). There is a positive correlation between mind wandering and poor sleep quality or difficulty falling asleep in the general population (Ottaviani and Couyoumdjian 2013) and a single night of sleep deprivation can increase mind wandering. Poor sleep quality as well as a range of sleep problems has also been linked to difficulties in emotion regulation and negative mood (Gruber and Cassoff 2014, Gobin, Banks et al. 2015, Palmer and Alfano 2017).

Default Mode Network Activity

The DMN consists of interconnected cortical regions, including ventromedial prefrontal cortex and posterior cingulate cortex, which are activated (positively correlated) during rest and deactivated (anti-correlated) in response to attentional demands (Buckner, Andrews-Hanna et al. 2008). Individuals with ADHD have disturbed DMN connectivity leading to hyperactivation of DMN during daily activities (Christakou, Murphy et al. 2013), which is hypothesised to lead to excessive mind wandering (Bozhilova, Michelini et al. 2018). Connectivity in the DMN can also be altered by any sleep-related reduction of consciousness (Horovitz, Braun et al. 2009), such as sleep deprivation (Gujar, Yoo et al. 2010, De Havas, Parimal et al. 2012, Dai, Liu et al. 2015). DMN is also one of the

crucial brain networks responsible for self-referential processing and emotion regulation (Andrews-Hanna 2012, Andrews-Hanna, Smallwood et al. 2014, Pan, Zhan et al. 2018) and failure to downregulate the DMN activity has been linked to depressive ruminations (Sheline, Barch et al. 2009). Finally, mind wandering is well-known to cause transient dysphoric mood (Killingsworth and Gilbert 2010).

Impairment

ADHD, mind wandering and poor sleep quality are all associated with increased rates of car accidents while driving (Lyznicki, Doege et al. 1998, Connor, Norton et al. 2002, Cowley 2013, Yanko and Spalek 2014) and together with emotional lability they all contribute to poor academic performance (Doi, Minowa et al. 2003, Barkley and Fischer 2010, Dewald, Meijer et al. 2010, Smallwood and Schooler 2015). Emotional lability leads to functional impairments in seven out of ten major life domains (Barkley and Fischer 2010).

Aim and Hypotheses

In summary, it is striking that ADHD, excessive mind wandering, poor sleep quality and emotional lability bear such a close resemblance in their negative effects on everyday functioning and share a close association with disrupted activity within the DMN. Despite this, these concepts have never been investigated together. Therefore, in the present study we aim to investigate the effect of mind wandering, emotional lability and sleep quality on the severity of symptoms of ADHD in a sample of adults diagnosed with ADHD. Based on the literature reviewed above, we hypothesize that all three variables will significantly exacerbate the symptomatology of ADHD. We further hypothesize that the independent variables will be causally linked: 1) mind wandering will lead to emotional lability (Killingsworth and Gilbert 2010) which would lead to ADHD symptom severity (Skirrow, McLoughlin et al. 2009, Barkley and Fischer 2010, Skirrow and Asherson 2013, Asherson, Buitelaar et al. 2016); and 2) poor sleep quality would lead to emotional lability (Gruber and Cassoff 2014, Gobin, Banks et al. 2015, Palmer and Alfano 2017) and mind wandering (Carciofo, Du et al. 2014, Poh, Chong et al.

2016), which would lead to ADHD symptom severity (Asherson, Buitelaar et al. 2016, Bozhilova, Michelini et al. 2018).

Methods

Sample

The data presented here is part of a larger study (Oils and Cognitive Effects in Adult ADHD Neurodevelopment, ClinicalTrials.gov Identifier: NCT01750307). In total 81 English-speaking adults with ADHD volunteered to participate in the study (60 male, 51 female, mean age 32.4 years, SD 10 years, mean IQ 110, SD 13). Diagnosis was made according to the DMS-5 criteria (American Psychiatric Association 2013). Participants were recruited via South London and Maudsley Adult ADHD Outpatient Services (see Table 1 for detailed characteristics).

Table 1 Background, clinical and cognitive variables of the study sample.

| Gender | Participants with ADHD | |
|-------------------------------|------------------------|----------------|
| | N=81 | 44 males (54%) |
| | Mean | SD |
| Age (years) | 33.5 | 10.3 |
| IQ | 109.4 | 13.7 |
| ADHD Symptom Severity (CAARS) | 65.7 | 15.7 |
| Emotional Lability (ALS) | 17.9 | 7.1 |
| Mind Wandering (MEWS) | 23.6 | 7.9 |
| Sleep Quality (PSQI) | 14.1 | 6.8 |

Note. MEWS: Mind Excessively Wandering Scale; PSQI: Pittsburgh Sleep Quality Index; ALS: Affective Lability Scale; CAARS: Conners' Adult ADHD Rating Scales.

Clinical measures

ADHD symptoms were measured using the Conners' Adult ADHD Rating Scales (CAARS) (Conners, Erhardt et al. 1999), a self-report 18-item scale assessing the level of inattention and hyperactivity/impulsivity consistent with the DSM-5 criteria for adult ADHD (American Psychiatric Association 2013). Emotional Lability was measured with the Affective Lability Scale (ALS) (Oliver and Simons 2004) a self-report 18-item scale sensitive to swift changes in emotion and mood.

Mind wandering was measured with the Mind Excessively Wandering Scale (MEWS) (Mowlem, Skirrow et al. 2016), a reliable self-report 12-item questionnaire developed on the basis of ADHD patients' descriptions of their thought processes: capturing thoughts constantly on the go, thoughts flitting from one topic to another and multiple overlapping thoughts at the same time. The MEWS is thought to be especially sensitive in detecting unintentional and uncontrollable mind wandering that is closely related to ADHD (Mowlem, Skirrow et al. 2016, Seli, Risko et al. 2016, Jonkman, Markus et al. 2017). MEWS has been validated against experience sampling data in daily life (Moukhtarian et al., unpublished data), and was significantly correlated with measures of spontaneous but not deliberate mind wandering in a community sample (Mowlem et al., unpublished data).

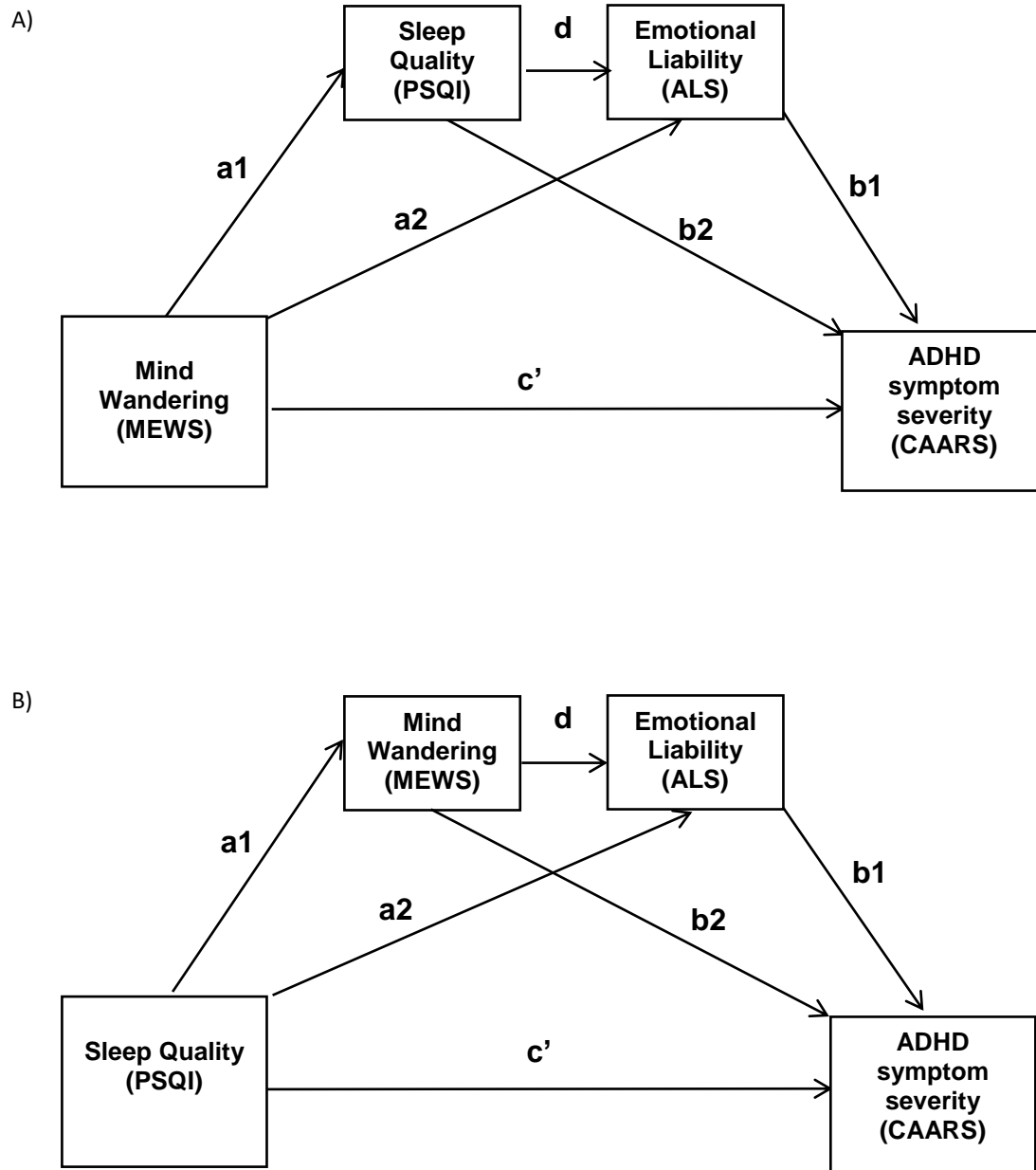
Sleep quality was measured using the Pittsburgh Sleep Quality Index (PSQI) (Buysse, Reynolds et al. 1989), a 19-item questionnaire with high validity and reliability in retrospective self-assessment of disturbed sleep quality over the last month, including the ensuing daytime dysfunction (Carpenter and Andrykowski 1998). PSQI broadly assess both quantitative (sleep latency, number of awakenings) and qualitative (restlessness, functioning) aspects of sleep and its utility is established in both clinical and non-clinical populations (Mollayeva, Thurairajah et al. 2016). PSQI covers several indications for sleep disorders using the following seven component scores: 1) subjective sleep quality; 2) sleep latency; 3) sleep duration; 4) habitual sleep efficiency; 5) sleep disturbances; 6) use of sleeping medication; 7) daytime dysfunction (Buysse, Reynolds et al. 1989). People with ADHD

who additionally suffer from sleep problems show difficulties across all these seven components (Mulraney, Sciberras et al. 2018).

Statistical analyses

We conducted serial multiple mediation modelling using ordinary least squares path analysis in PROCESS (Hayes 2013). For the estimation of the indirect effects of the independent variables on the outcome variable via the intermediary variables we used 95% bias-corrected bootstrap confidence intervals (CI) based on 10,000 bootstrapping samples. A confidence interval was considered statistically significant when it was entirely above or below zero. The two-tailed alpha was set at 0.05 for all analyses.

Figure 1 A) Serial multiple mediation model of sleep quality and emotional liability on the effect of mind wandering on ADHD symptom severity; B) Serial multiple mediation model of mind wandering and emotional liability on the effect of sleep quality on ADHD symptom severity.



Note. MEWS: Mind Excessively Wandering Scale; PSQI: Pittsburgh Sleep Quality Index; ALS: Affective Liability Scale; CAARS: Conners' Adult ADHD Rating Scales.

Results

A multiple regression was run to predict ADHD symptom severity from mind wandering, sleep quality and emotional lability (see Figure 1). There was linearity as assessed by partial regression plots and a plot of studentized residuals against the predicted values. There was independence of residuals, as assessed by a Durbin-Watson statistic of 1.970. There was homoscedasticity, as assessed by visual inspection of a plot of studentized residuals versus unstandardized predicted values. There was no evidence of multicollinearity, as assessed by tolerance values greater than 0.1. The assumption of normality was met, as assessed by a Q-Q Plot.

The multiple regression model statistically significantly predicted ADHD symptom severity, $F(3, 74) = 86.969$, $p < .001$. R^2 for the overall model was 77.9% with an adjusted R^2 of 77.0%, a large size effect according to Cohen (1988). Mind wandering and emotional lability added statistically significantly to the prediction, $p < .05$. Regression coefficients and standard errors are presented in Table 2.

Table 2 Summary of Multiple Regression Analysis.

| Variable | B | SE_B | β | Sig. |
|--------------------|--------|--------|---------|-------|
| Intercept | 25.464 | 2.913 | | 0.000 |
| Mind wandering | 0.419 | 0.136 | 0.212 | 0.003 |
| Sleep Quality | 0.067 | 0.14 | 0.029 | 0.634 |
| Emotional Lability | 1.614 | 0.152 | 0.73 | 0.000 |

Note. B = unstandardized regression coefficient; SE_B = Standard error of the coefficient; β = Standardized coefficient.

All study variables were significantly positively correlated, see Table 3.

Table 3 Summary Correlations.

| Variable | Mind Wandering (MEWS) | Sleep Quality (PSQI) | Emotional Lability (ALS) | ADHD Symptom Severity (CAARS) |
|-----------------------------|--------------------------|-------------------------|-----------------------------|----------------------------------|
| Mind Wandering (MEWS) | | 0.389 | 0.575 | 0.639 |
| Sleep Quality (PSQI) | | | 0.377 | 0.387 |
| Emotional Lability (ALS) | | | | 0.867 |

Note. MEWS: Mind Excessively Wandering Scale; PSQI: Pittsburgh Sleep Quality Index; ALS: Affective Lability Scale; CAARS: Conners' Adult ADHD Rating Scales. All correlations are statistically significant at the level 0.001, two-tailed.

As mediators in model A (emotional lability and sleep quality) were significantly correlated, $r(78) = 0.377$, $p < 0.001$) as well as in model B (mind wandering and emotional lability), $r(78) = 0.575$, $p < 0.001$ we run a serial multiple mediation models.

Model A

The model (see Table 4) was statistically significant, $R = 0.65$, $R^2 = 0.42$, $F(1,76) = 54.84$, $p < 0.001$. We found a significant direct effect of mind wandering on ADHD symptom severity ($c' = 0.42$, $p = 0.003$). There was a strong association between mind wandering and emotional lability ($a_2 = 0.46$, $p < 0.001$) as well as between mind wandering and sleep quality ($a_1 = 0.33$, $p = 0.000$). We found a significant effect of emotional lability on ADHD symptom severity ($b_2 = 1.61$, $p < 0.001$), but no effect of sleep quality on ADHD symptom severity ($b_1 = 0.07$, $p = 0.634$). The effect of mind wandering on ADHD symptom severity was mediated by emotional lability ($Ind3 = 0.74$, 95% CI 0.49 to 1.04), but not sleep quality ($Ind1 = 0.02$, 95% CI: -0.07 to 0.13). However, the interaction between the mediators also yielded a statistically significant mediatory effect where sleep quality affected emotional lability ($Ind2 = 0.10$, 95% CI 0.01 to 0.25).

Model B

The model (see Table 5) was statistically significant, $R = 0.39$, $R^2 = 0.15$, $F(1,76) = 13.38$, $p = 0.001$. There was no statistically significant direct effect of sleep quality on ADHD symptom severity ($c' = 0.07$, $p = 0.634$). There was a strong effect of sleep quality on mind wandering ($a1 = 0.45$, $p < 0.001$), but no significant effect of sleep quality on emotional lability ($a2 = 0.19$, $p = 0.079$). Again, we found a significant effect of mind wandering on ADHD symptom severity ($b1 = 0.42$, $p = 0.003$), as well as emotional lability on ADHD symptom severity ($b2 = 1.61$, $p < 0.001$). As there was no significant direct effect, the influence of sleep quality on ADHD symptom severity was completely mediated by mind wandering ($Ind1 = 0.19$, 95% CI 0.06 to 0.41) and emotional lability ($Ind3 = 0.30$, 95% CI 0.01 to 0.62). The interaction between the mediators was also statistically significant ($Ind2 = 0.34$, 95% CI 0.16 to 0.60).

Table 4 Results from the serial multiple mediation model of the intermediary effect of sleep quality and emotional lability on the relationship between mind wandering and ADHD symptom severity.

| Mediators: (1) Sleep Quality (PSQI) and (2) Emotional Lability (ALS) | | | | |
|--|--|------|-----------------------|-------|
| | Coefficient/ Effect | SE | t | p |
| Mind Wandering (MEWS) ---> ADHD Symptom Severity (CAARS) | | | | |
| a1 | 0.33 | 0.09 | 3.68 | 0.000 |
| a2 | 0.46 | 0.09 | 5.12 | 0.000 |
| b1 | 0.07 | 0.14 | 0.48 | 0.634 |
| b2 | 1.61 | 0.15 | 10.65 | 0.000 |
| d | 0.19 | 0.10 | 1.78 | 0.079 |
| c' | 0.42 | 0.14 | 3.08 | 0.003 |
| c | 1.28 | 0.17 | 7.41 | 0.000 |
| Ind1 | 0.02 | 0.05 | 95% CI: -0.07 to 0.13 | |
| Ind2 | 0.10 | 0.06 | 95% CI: 0.01 to 0.25 | |
| Ind3 | 0.74 | 0.14 | 95% CI: 0.49 to 1.04 | |
| model | R = 0.65, R ² = 0.42, F(1,76) = 54.84 | | | 0.000 |

Note. MEWS: Mind Excessively Wandering Scale; PSQI: Pittsburgh Sleep Quality Index; ALS: Affective Lability Scale; CAARS: Conners' Adult ADHD Rating Scales; CI: 95% Bootstrapping Confidence Intervals

c': direct effect of the independent variable (Emotional Lability in A or Sleep Quality in B) on the outcome variable (ADHD Symptom Severity);

a: effect of the independent variable on the intermediary variable (Emotional Lability in A or Sleep Quality in B);

b: effect of the intermediary variable on the outcome variable;

c: total effect, which is the sum of the direct and indirect effects;

d: serial effect of mediator 1 (Sleep Quality) on mediator 2 (Emotional Lability);

Ind: indirect effect of the independent variable on the outcome variable via the intermediary variables;

Ind1: MEWS ---> PSQI ---> CAARS

Ind2: MEWS ---> PSQI ---> ALS ---> CAARS

Ind3: MEWS ---> ALS ---> CAARS

Table 5 Results from the serial multiple mediation model of the intermediary effect of mind wandering and emotional lability on the relationship between sleep quality and ADHD symptom severity.

| Mediators: (1) Mind Wandering (MEWS) and (2) Emotional Lability (ALS) | | | | |
|---|--|------|----------------------|-------|
| | Coefficient/ Effect | SE | t | p |
| Sleep Quality (PSQI) ---> ADHD Symptom Severity (CAARS) | | | | |
| a1 | 0.45 | 0.12 | 3.68 | 0.000 |
| a2 | 0.19 | 0.10 | 1.78 | 0.079 |
| b1 | 0.42 | 0.14 | 3.08 | 0.003 |
| b2 | 1.61 | 0.15 | 10.65 | 0.000 |
| d | 0.46 | 0.09 | 5.12 | 0.000 |
| c' | 0.07 | 0.14 | 0.48 | 0.634 |
| c | 0.89 | 0.24 | 3.66 | 0.001 |
| Ind1 | 0.19 | 0.09 | 95% CI: 0.06 to 0.41 | |
| Ind2 | 0.34 | 0.11 | 95% CI: 0.16 to 0.60 | |
| Ind3 | 0.30 | 0.16 | 95% CI: 0.01 to 0.62 | |
| model | R = 0.39, R ² = 0.15, F(1,76) = 13.38 | | | 0.001 |

Note. MEWS: Mind Excessively Wandering Scale; PSQI: Pittsburgh Sleep Quality Index; ALS: Affective Lability Scale; CAARS: Conners' Adult ADHD Rating Scales; CI: 95% Bootstrapping Confidence Intervals

c': direct effect of the independent variable (Emotional Lability in A or Sleep Quality in B) on the outcome variable (ADHD Symptom Severity);

a: effect of the independent variable on the intermediary variable (Emotional Lability in A or Sleep Quality in B);

b: effect of the intermediary variable on the outcome variable;

c: total effect, which is the sum of the direct and indirect effects;

d: serial effect of mediator 1 (Sleep Quality) on mediator 2 (Emotional Lability);

Ind: indirect effect of the independent variable on the outcome variable via the intermediary variables;

Ind1: PSQI ---> MEWS ---> CAARS

Ind2: PSQI ---> MEWS ---> ALS ---> CAARS

Ind3: PSQI ---> ALS ---> CAARS

Discussion

We found that mind wandering and emotional lability predicted ADHD symptom severity and that mind wandering, emotional lability and sleep quality are all linked and significantly contribute to the symptomatology of adult ADHD. The mediation models supported both our prior hypotheses. Mind wandering was found to lead to emotional lability which in turn leads to ADHD symptom severity; and poor sleep quality was found to exacerbate mind wandering leading to ADHD symptoms.

Our findings fit well into the previous findings. We confirmed that mind wandering and emotional lability are significantly linked with core deficits in adult ADHD (Skirrow, McLoughlin et al. 2009, Barkley and Fischer 2010, Skirrow and Asherson 2013, Seli, Smallwood et al. 2015, Asherson, Buitelaar et al. 2016, Mowlem, Skirrow et al. 2016, Franklin, Mrazek et al. 2017, Bozhilova, Michelini et al. 2018) and that poor sleep quality may lead to emotional dysregulation (Gruber and Cassoff 2014, Gobin, Banks et al. 2015, Palmer and Alfano 2017) as well as exacerbate mind wandering (Carciofo, Du et al. 2014, Poh, Chong et al. 2016). We have also confirmed an influential result that mind wandering could lead to emotional lability and negative emotions (Killingsworth and Gilbert 2010).

Limitations

It should be noted, that even though we would like to hypothesise that the links between the variables are causal and despite the fact that the mediation model itself encourages a causal interpretation of the links between the variables (Hayes 2013), the cross-sectional nature of our data limits the causal inferences that can be drawn from these analyses (Winer, Cervone et al. 2016). Therefore, we based our model on a specific a priori hypothesis developed based on a theoretical model that arises from empirical observations linking the constructs investigated here (Axelrod, Rees et al. 2015, Gallo and Posner 2016). To investigate the causal nature of these hypotheses, further studies using a longitudinal design or experimental manipulations will be required.

Mind Wandering and Emotional Lability

Here we have investigated a specific hypothesis that mind wandering leads to emotional lability. This is based on one of the most influential studies in the field, investigating mind wandering in a neurotypical group, where it has been found that mind wandering was the cause, and not a consequence, of negative feelings (Killingsworth and Gilbert 2010). However, another prominent study found that negative mood can lead to more mind wandering (Smallwood, Fitzgerald et al. 2009) and today it is generally acknowledged that emotional processes play a major, if not the central, role in generation of mental content during mind wandering (Smallwood and Schooler 2015). It seems that mind wandering and emotional lability are so closely linked that a two-way process might be a best explanation for the existing data. Mind wandering is a cause of emotional dysregulation when the negative content of the thought or the intrusive nature of mind wandering itself, leads to higher levels of stress, including emotional distress, which in turn enhances the level of task-unrelated, negatively-valenced thoughts. Such a mechanism seems to be especially plausible in adults with ADHD, as the mind wandering experiences in ADHD are more intrusive and excessive (Bozhilova, Michelini et al. 2018) and there is emotional overactivity to stressful events (Skirrow and Asherson 2013). Mind wandering and emotional lability in adults with ADHD are both an integral part of the disorder (Asherson, Buitelaar et al. 2016) and this may be underpinned by abnormal activity in the default mode network (Shaw, Stringaris et al. 2014, Bozhilova, Michelini et al. 2018). This reasoning can be additionally supported by the fact that mindfulness-based treatments for adults with ADHD seem to be promising and the preliminary data suggest high efficacy (Cairncross and Miller 2016). Mindfulness and meditation practices are known to normalize activity and connectivity in the DMN and lead to decreed mind wandering and lead to improved emotion regulation (Mitchell, Zylowska et al. 2015). Further work is however needed to test the further hypotheses arising from our study.

Sleep, emotional lability and mind wandering

We found a similar bi-directional relationship between sleep quality and mind wandering, which is in line with previous findings in neurotypical subjects (Carciofo, Du et al. 2014). It seems that not only poor sleep quality and the resulting sleep deprivation leads to higher incidence of mind wandering (Poh, Chong et al. 2016), but also a restless wandering mind makes it harder to fall asleep. It should be noted that one of the items on the MEWS scale used to measure mind wandering in our study says: “Because my mind is ‘on the go’ at bedtime, I have difficulty falling off to sleep” (Mowlem, Skirrow et al. 2016). Mind wandering and sleepiness are similar in terms of the EEG signal and are both linked to the DMN activity (Braboszcz and Delorme 2011). Moreover, poor sleep quality results in negative affect (Carciofo, Du et al. 2014), which is also in line with our findings regarding sleep quality and emotional lability. As discussed above, because mind wandering and emotional lability are so closely linked via negative affect, even when poor sleep quality exacerbates one of the variables, inevitably both of them will be increased (McVay, Kane et al. 2009, Ottaviani and Couyoumdjian 2013), especially in adults suffering from ADHD.

Future directions

In summary, this study aimed to link the currently mostly independently investigated concepts of emotional lability, mind wandering, sleep quality and adult ADHD. Future studies should employ experimental on-task measures of mind wandering (experience sampling), sleepiness (event-related potentials, quantitative electroencephalography and polysomnography) and frustration tasks to objectively measure emotional lability; and link them to the activity of the DMN using neuroimaging and experimental designs involving ADHD medication and mindfulness training. Investigating these concepts in diverse samples, across developmental stages and diagnostic categories holds a big promise in fully uncovering the causal mechanism behind these impairing deficits.

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Declaration of Interest

Professor Asherson has received funds for consultancy on behalf of KCL to Shire, Eli-Lilly, and Novartis, regarding the diagnosis and treatment of ADHD; educational/research awards from Shire, Eli-Lilly, Novartis, Vifor Pharma, GW Pharma, and QbTech; speaker at sponsored events for Shire, Eli-Lilly, and Novartis. All funds are used for studies of ADHD. Ruth Cooper has received funding from Vifor Pharma. The other authors report no conflicts of interest.

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